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THEORETICAL AND EXPERIMENTAL INVESTIGATION OF THE EFFECT OF ELECTROSTATIC CHARGING ON THE BEHAVIOR OF LIQUID SPRAYS

By

Eng. Hesham El-Sayed Abdel Hameed

B.Sc., M.Sc. Mechanical Power Engineering

A Thesis Submitted to

the Faculty of Engineering at Cairo University

in Partial Fulfillment of the Requirements for the Degree of

Doctor of Philosophy in Mechanical Power Engineering

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GIZA, EGYPT
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ABSTRACT

This work is concerned with enhancing dispersion in sprays and jets. This is considered through adopting two approaches; droplet electrostatic charging and noncircular injection nozzles. Regarding the first, spray behavior under the effect of superimposed electrostatic charge has been studied both experimentally and computationally. In the experimental work, liquid atomization was achieved using an air assisted, single-hole atomizer. The liquid is charged using inductive technique. The experimental test rig is equipped with all necessary injection components, charging facility and two-dimensional traverse mechanism. Both the phase Doppler particle analyzer and CCD video camera were used in the measurements. Detailed measurements of the spray droplet size distribution, liquid flux, spray cone angle and charging current have been obtained. The effect of parameters such as charging current, injection pressure and liquid viscosity have been considered. In the computational study the governing equations for both gas and liquid phases have been solved using an arbitrary Lagrangian Eulerian algorithm. Complete two-way coupling between the two phases is considered. A modified k-ε model for the turbulence is used. The model considers the impact of the spray droplets on generation as well as destruction of the turbulence. Also the impact of the mutual interaction between the spray droplets on their drag characteristics is considered. Regarding the effect of the electrostatic charging it is modeled through its impact on breakup and repulsion. Also its effect on the droplet probability density function is considered by adopting the concept of the minimum energy theory. Both the design and operating parameters are kept the same in both the experimental and computational studies to facilitate the comparison. According to the obtained results it has been found that, both the experimental and computational results are consistent. Also it has been found that increasing the spray charge leads to a reduction in the droplet size as well as the spray core flux. On the contrary, liquid axial flux increases at the spray edge. Fine droplet concentration on the spray boundary increases due to the created lateral flux and early breakup of droplets. The fine droplets track the electric field created by the inductive charging ring. The drawn charge increases linearly with the increase in the liquid flow rate as well as the applied charging voltage. Droplet size decreases due to the increase in the injection pressure of a charged spray. Also the droplet size increases with the increase in the liquid viscosity of the charged spray. The effect of these parameters is almost consistent with that found in the uncharged spray. Regarding the second part of this work, which covers the effect of noncircular injection nozzle on the dispersion of two-phase jet, a direct numerical simulation code was developed to simulate this problem. Lagrangian approach is adopted for the droplet phase with each individual droplet being solved with complete two way coupling. Due to the limitation of the computational capability of the currently

available supercomputers the solution is restricted to Reynolds number equal 500. According to the obtained results it has been found that, the two-phase jets entrain more gas than the single-phase counterpart. Also the potential core of the two-phase jet is one order of magnitude lower than the single-phase counterpart. The noncircular jets, specifically the elliptic, rectangular and triangular have much higher entrainment gas compared with the circular jet. Concerning the droplet number density, liquid mass and evaporated species distributions, it is shown that the elliptic jet is the optimal configuration for combining good droplet dispersion with good vapor mixing characteristics.

This work is important in the areas of improving mixture preparations in combustion systems, environmental studies and other spray processes.

CONTENTS

Page

ACKNOWLEDGEMENT.....i

ABSTRACT.....ii

CONTENTS.....iv

LIST OF TABLES.....vi

LIST OF FIGURES.....vii

NOMENCLATURE.....xii

1. INTRODUCTION.....1-1

2. LITERATURE REVIEW.....2-1

2.1 INTRODUCTION.....2-1

2.2 CHARGED DROP INSTABILITY.....2-2

2.3 DROP DISINTEGRATION.....2-5

2.4 PROCESSES OF CHARGING DROPLETS.....2-9

2.5 PREVIOUS WORKS ON CHARGED SPRAY.....2-10

2.6 IMPROVING DISPERSION THROUGH USE OF NONCIRCULAR NOZZLE.....2-20

2.7 DISCUSSION OF PREVIOUS WORKS AND PLAN OF THE PRESENT WORK.....2-22

3. EXPERIMENTAL SETUP.....3-1

3.1 INTRODUCTION.....3-1

3.2 EXPERIMENTAL TEST RIG.....3-2

3.3 MEASURING TECHNIQUE.....3-13

3.4 UNCERTAINTY ANALYSIS.....3-15

3.5 CONDITIONS COVERED EXPERIMENTALLY.....3-24

4. NUMERICAL MODEL FOR AN ELECTROSTATIC CHARGED SPRAY.....4-1

4.1 INTRODUCTION.....4-1

4.2 GOVERNING EQUATIONS.....4-2

4.3 BOUNDARY CONDITIONS.....4-9

4.4 INITIAL CONDITIONS.....4-10

4.5 NUMERICAL SOLUTION.....4-10
4.6 BREAKUP MODEL.....4-17
4.7 ACCURACY AND SELECTION OF THE TIME STEP.....4-21
5. EXPERIMENTAL AND NUMERICAL RESULTS FOR ELECTROSTATIC CHARGED SPRAY.....5-1
5.1 INTRODUCTION.....5-1
5.2 CHARACTERISTICS OF UNCHARGED SPRAY.....5-2
5.3 SPRAY CHARACTERISTICS UNDER A SUPERIMPOSED ELECTROSTATIC CHARGING.....5-4
5.4 EFFECT OF WORKING PARAMETERS ON CHARGED SPRAY.....5-18
5.5 NUMERICAL RESULTS.....5-29
5.6 NUMERICAL RESULTS OF UNCHARGED SPRAY.....5-32
5.7 RESULTS OF CHARGED SPRAY.....5-35
6. EFFECT OF INJECTION GEOMETRY ON DISPERSION OF TWO PHASE JET FLOWS.....6-1
6.1 INTRODUCTION.....6-1
6.2 MODEL.....6-2
6.3 NUMERICAL SOLUTION.....6-11
6.4 FLOW CONFIGURATION AND INITIAL CONDITIONS.....6-12
6.5 RESULTS.....6.14
7. SUMMARY AND CONCLUSIONS.....7-1
8. REFERENCES.....8-1
APPENDIX A SOLUTION SCHEME.....A-1
1. Lagrangian Phase.....A-1
2. Pressure Prediction for Implicit Phase B Equations.....A-7
3. The Rezoning Phase (Phase C).....A-10
ARABIC SUMMARY

LIST OF TABLES

Page

Table (2.1) The relation between the number of siblings and their mass ratio.....2-8

Table (2.2) Comparisons among common droplet charging methods.....2-11

Table (3.1) Conditions covered experimentally.....3-25

Table (6.1) Properties used in the simulations (evaluated at Atmospheric pressure and T=350 K from correlations for air and decane found in Miller et al., 1998). The subscripts L, C and V denote the liquid, carrier gas and evaporated vapour, repectively.....6-15

Table (6.2) Geometries, aspect ratio (AR), and time at which a mass flux steady state condition was achieved for the single and two phase flow simulations.....6-15